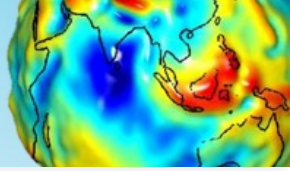
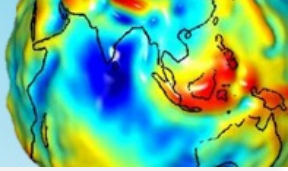


Mass Change General Study Plan

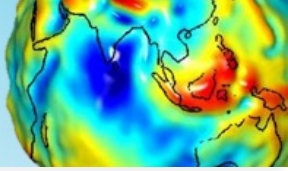
Bernie Bienstock
Jet Propulsion Laboratory, California Institute of Technology
MC Study Coordinator
July 30, 2019

Mass Change Overall Study Objectives



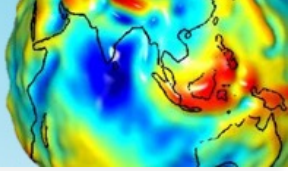
- Identify and characterize a diverse set of high value Mass Change (MC) observing architectures responsive to the Decadal Strategy (DS) report's scientific and application objectives for MC
- Assess the cost effectiveness of each of the studied architectures
- Perform sufficient in-depth design of up to three selected architectures to enable rapid initiation of a Phase A Study
- Multi-center study
  - JPL Lead
  - GSFC
  - LaRC
  - ARC

Mass Change Measurement Techniques



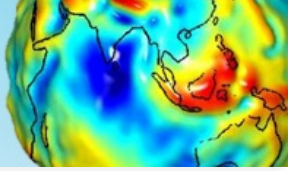
- Measure changes in gravitational potential by observing the forces acting on a spacecraft
- Fundamentally different measurement from passive radiometry or active sensors having traditional sensor fields of view
- MC measurements have an intrinsic relationship between
  - Observing architecture
  - Optimized data processing

Program of Record – GRACE-FO



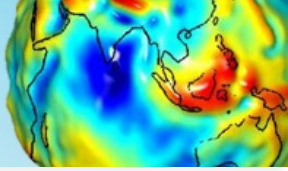
- Twin S/C launched on 5/22/18
- Continues GRACE measurements of tracking Earth's water movement to monitor changes in
  - Underground water storage
  - Amount of water in large lakes and rivers, soil moisture, ice sheets and glaciers, and sea level caused by the addition of water to the ocean
- Limited life mission

Innovation Opportunities



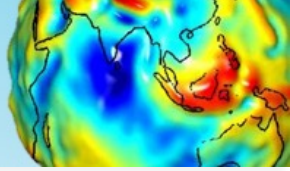
- Gravity gradiometry based architectures
- Use of constellations of satellites with only positioning information and/or low-resolution crosslinks
- Feasibility and impacts of propulsive systems to raise the spacecraft altitude and lengthen mission duration
- Small satellite buses and the capabilities of those flight systems
- Benefits of compact, low-power electronic accelerometers, optical mechanical inertial, and drag compensation systems

New Technology Opportunities



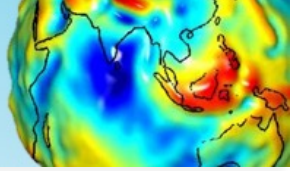
- Atomic Interferometer Gravity Gradiometer instrument
- Raising the reliability of the GRACE-FO Laser Ranging Interferometer (LRI), a technology demonstration, from Class D to Class C
- Opto-mechanical inertia sensors to replace ACC
- Emerging quantum inertia sensors to replace ACC
- Compact Coherent Laser Ranging (CCLR) instrument enabling high precision optical range and range rate measurements in a low-power low-mass application

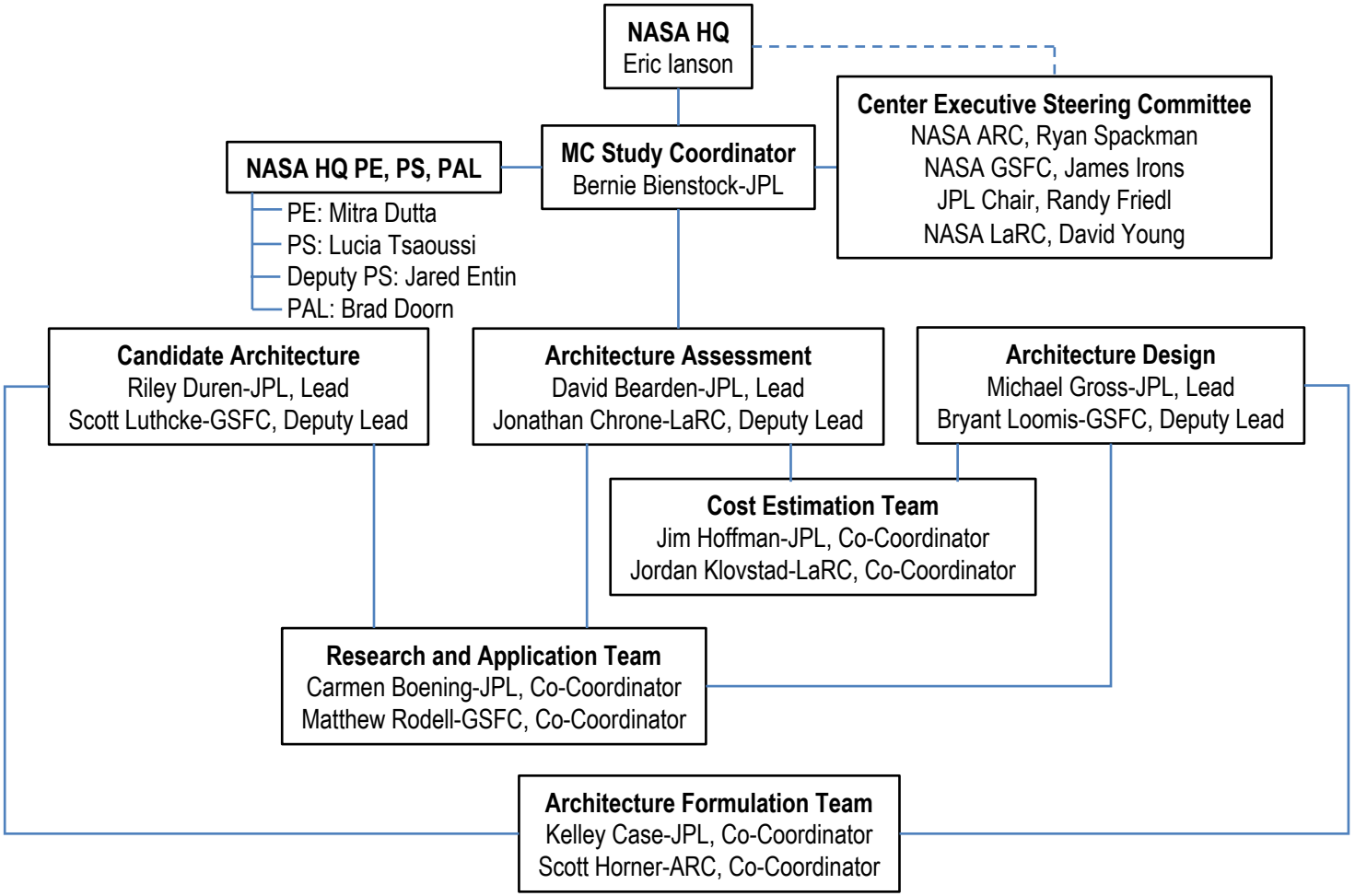
Enabling Partnerships



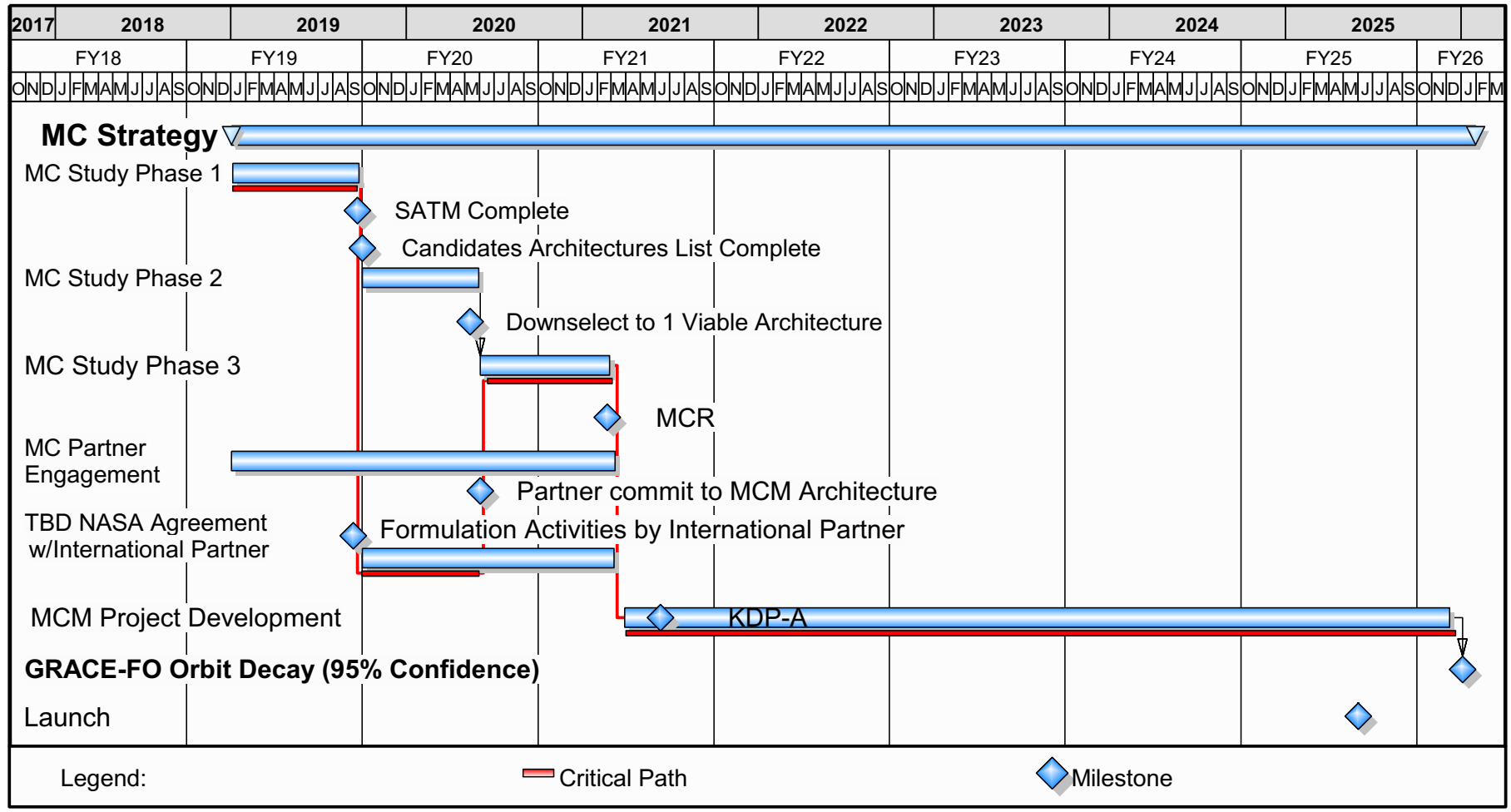
- Strong interest and willingness to participate in potential MC missions by the German (DLR) and European (ESA) space agencies
- Potential interest with appropriate levels of management of the space agencies of other countries, including EU, UK, India, France, Italy, Japan, Vietnam, Argentina, Brazil and Australia) in order to seek international partnerships for an MC mission
- Enabling partnerships and potential providers will also span industry capabilities, university and non-NASA participation
- Engagement with other US Agencies (NOAA, USGS) to gauge their interest in partnering for a MC mission.

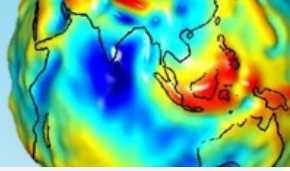
Study Organization





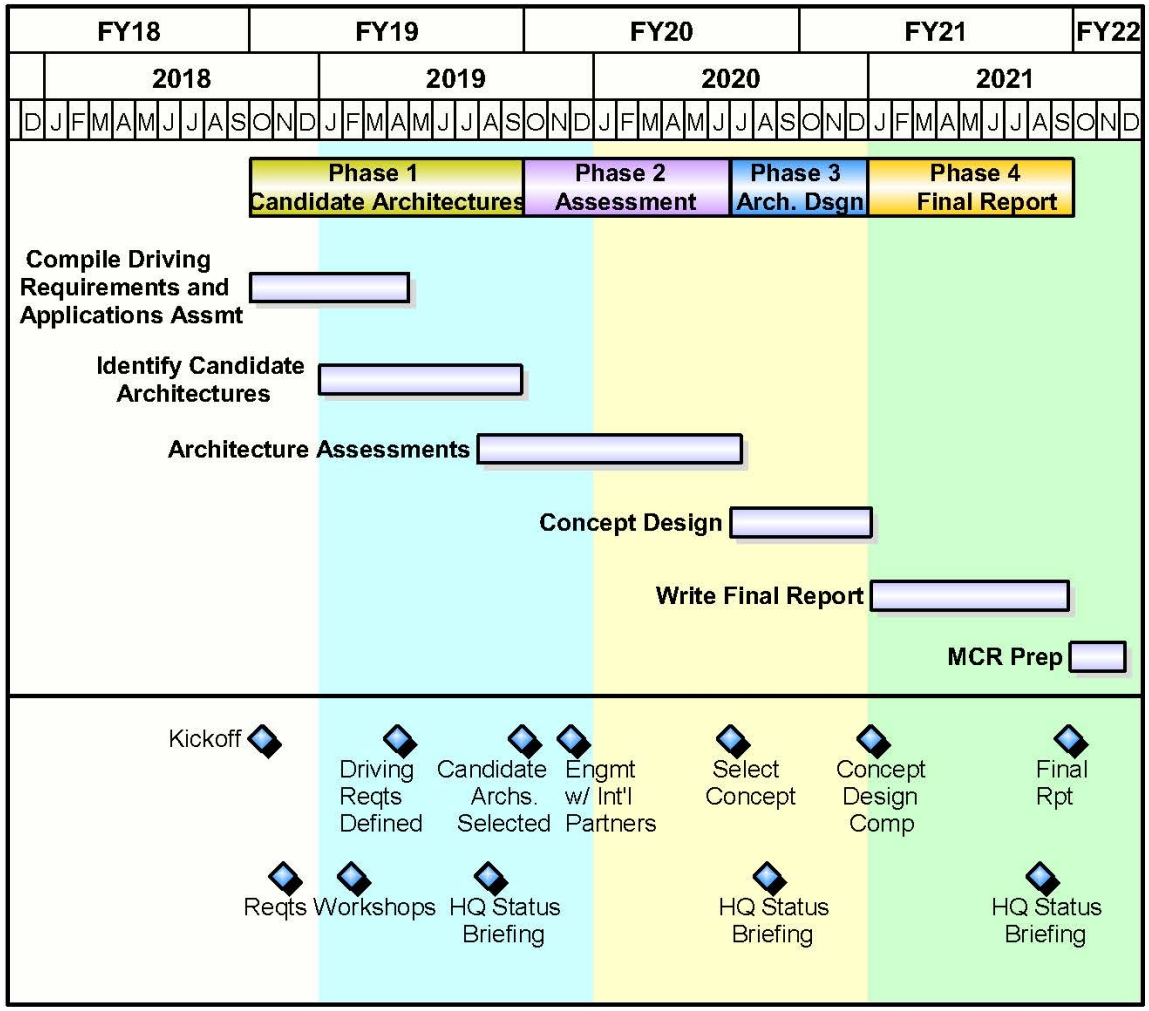
Overall Study Schedule



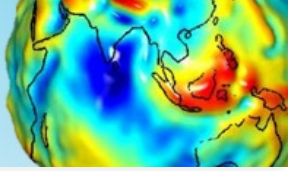


Backup

Original Overall Study Schedule



NASA Program Phase Definitions



Formulation

- Phase A – Mission Concept and Requirements Definition and Technology Development
- Phase B – Preliminary Design and Technology Completion

Approval (Confirmation)

Implementation

- Phase C – Final Design and Fabrication
- Phase D – System Assembly, Integration and Test, and Launch (extending through in-space checkout)
- Phase E – Operations and Sustainment
- Phase F – Closeout